World Water Congress XV
International Water Resources Association (IWRA)
Edinburgh, Scotland. 25th to 29th May 2015

Hydropower – factoring in climate change

1. **Global Supply & Potential**
2. **Principles of Power Generation**
3. **Climate Aspects**
4. **Sustainability Aspects**

Richard M. Taylor, FEI
CEO, International Hydropower Association

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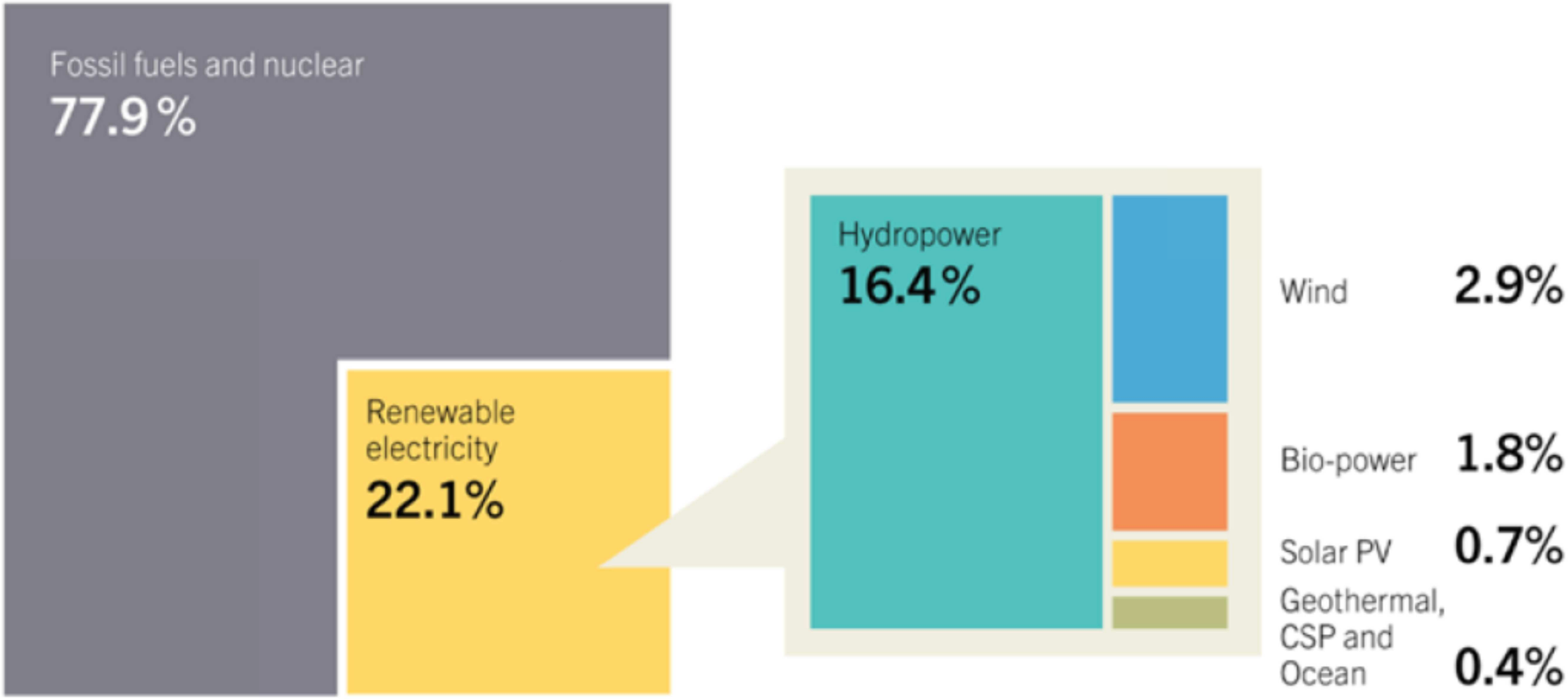
international hydropower association

Renewable energy's share of global electricity production

Global Overview

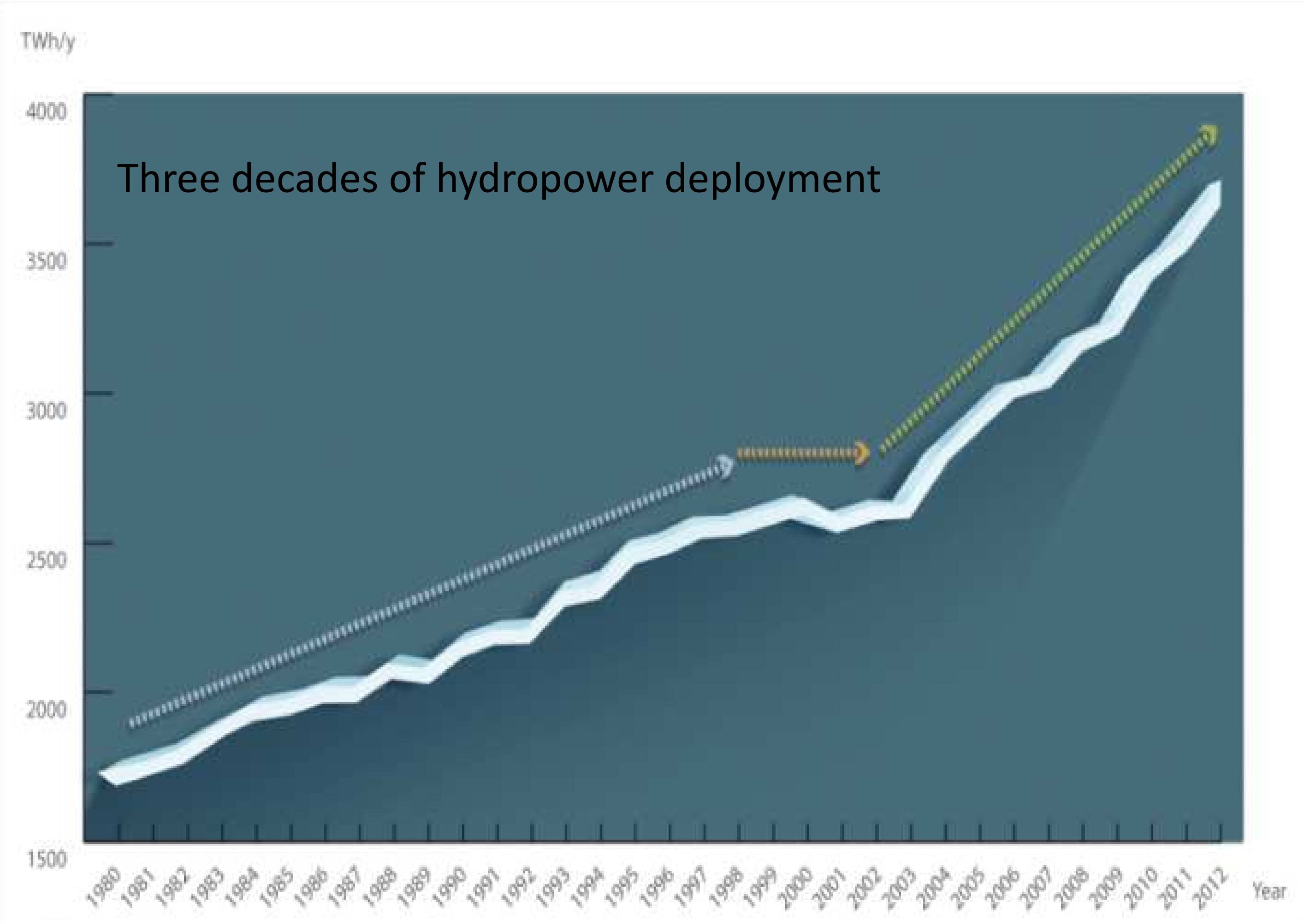


RENEWABLES 2014
GLOBAL STATUS REPORT

Source: REN21 Renewables 201… us Report

Growth in hydropower deployment

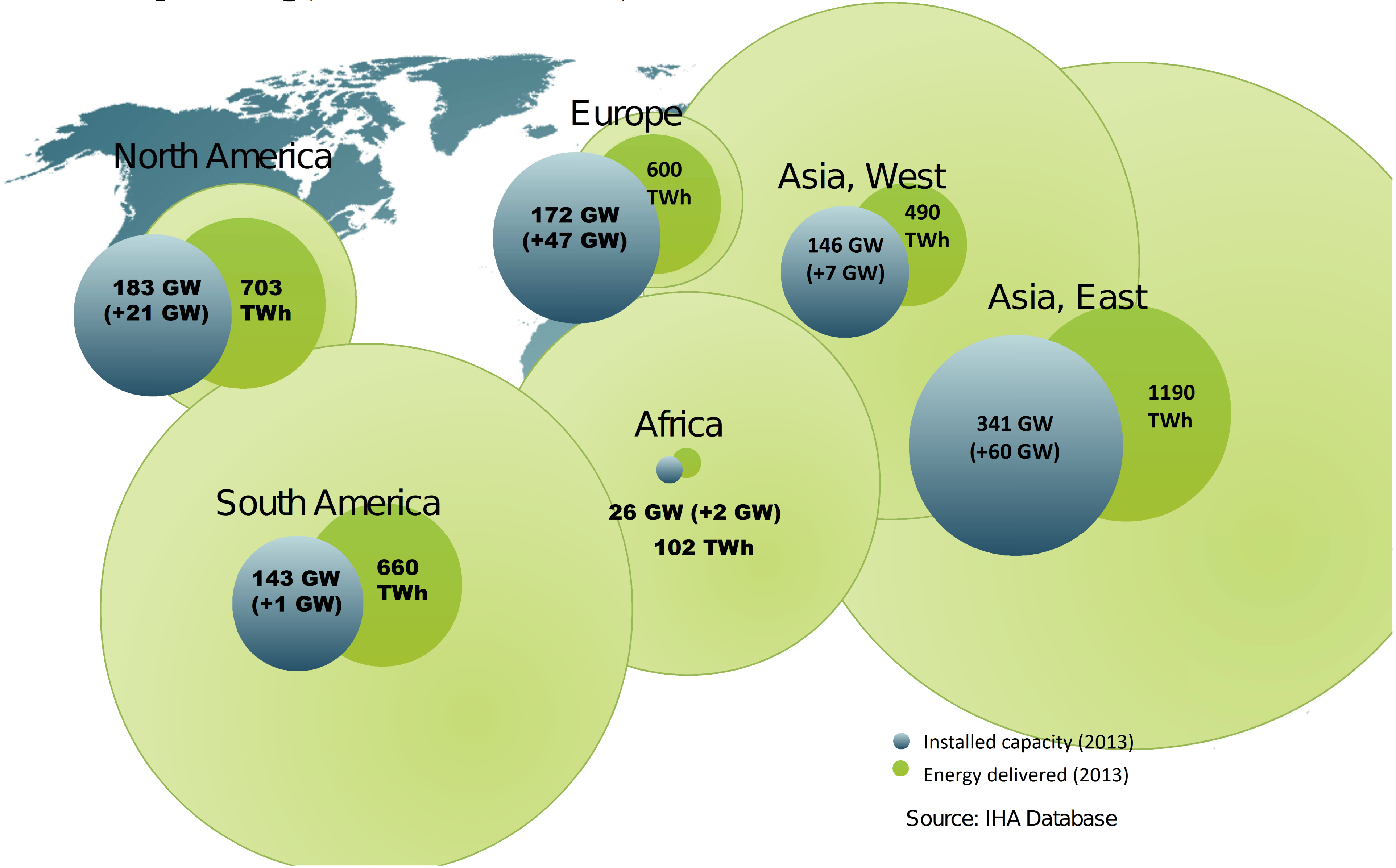
Global Overview



Regional hydropower (inc. pumped storage capacity)

Regional Hydropower (+Pumped Storage)

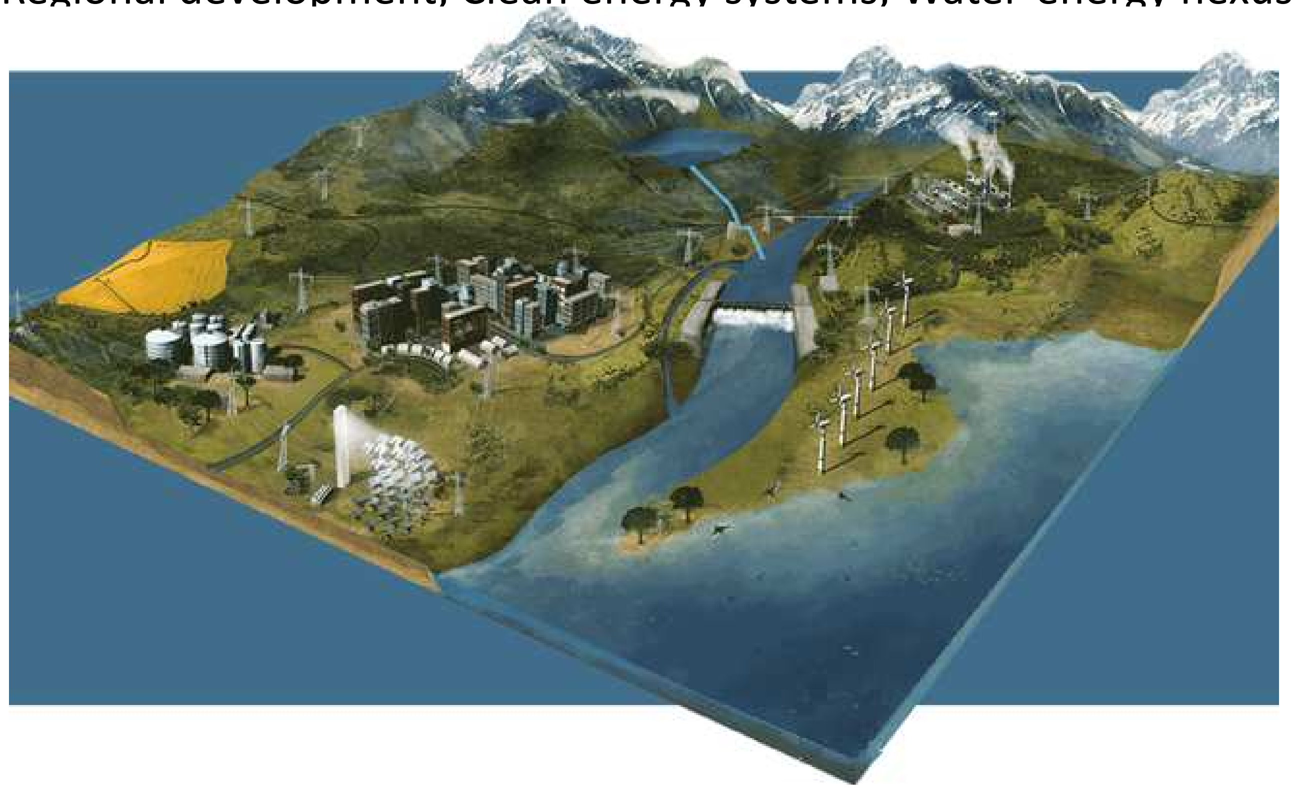
Capacity, Generation, Potential



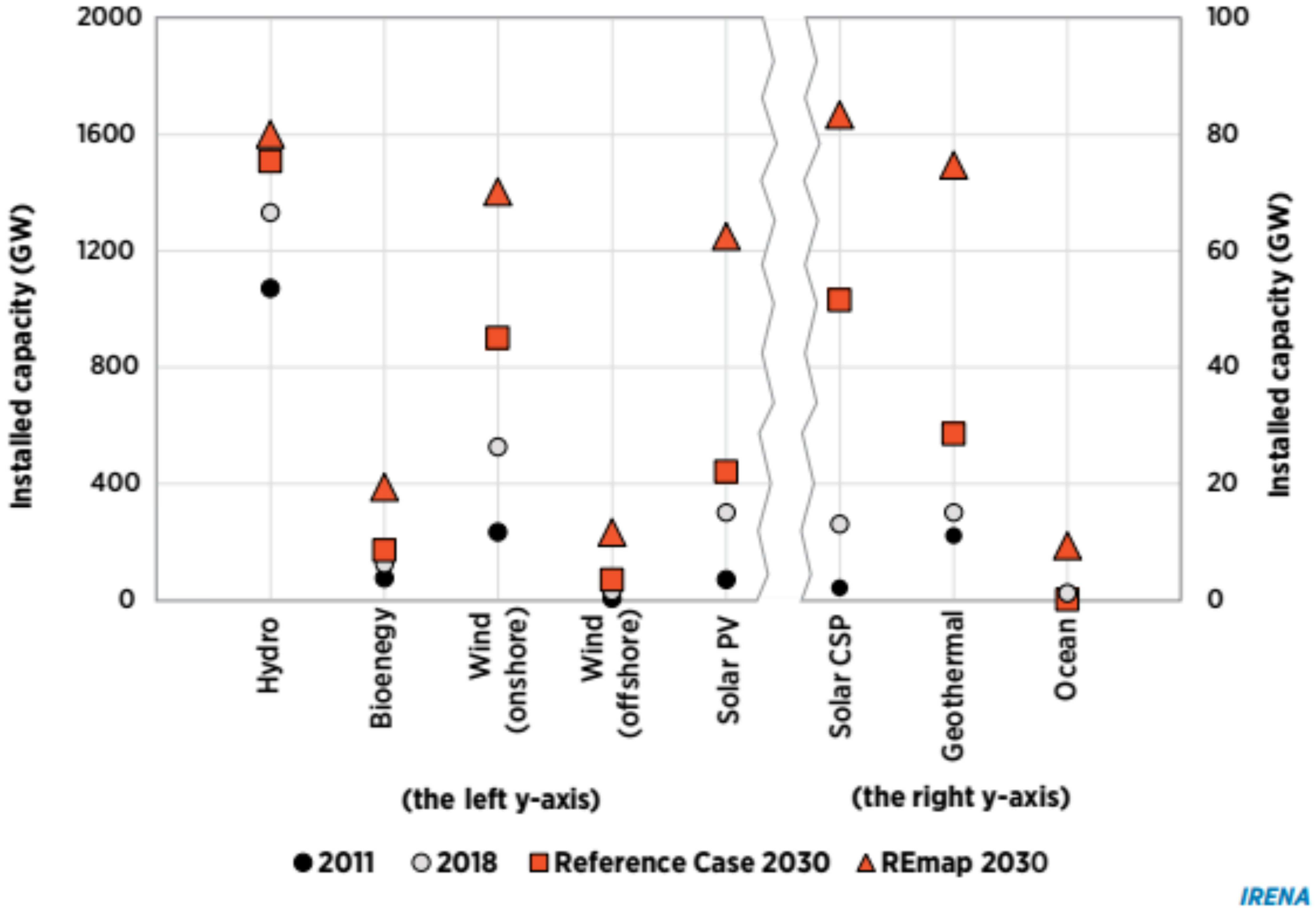
Drivers for new investment in hydropower

Clean Energy and Regional Development

Regional development, Clean energy systems, Water-energy nexus



Projected 2030 deployment, by source



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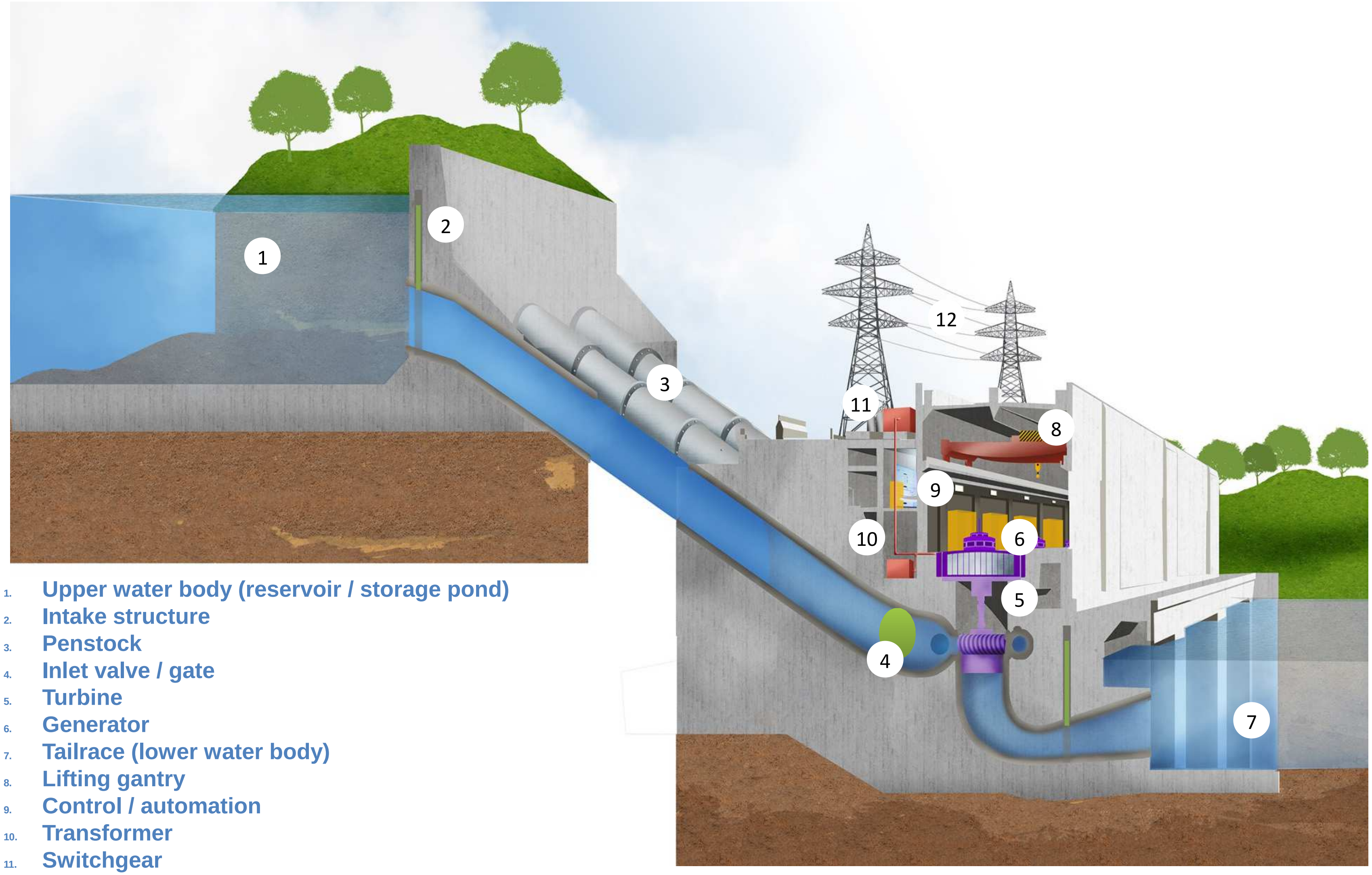
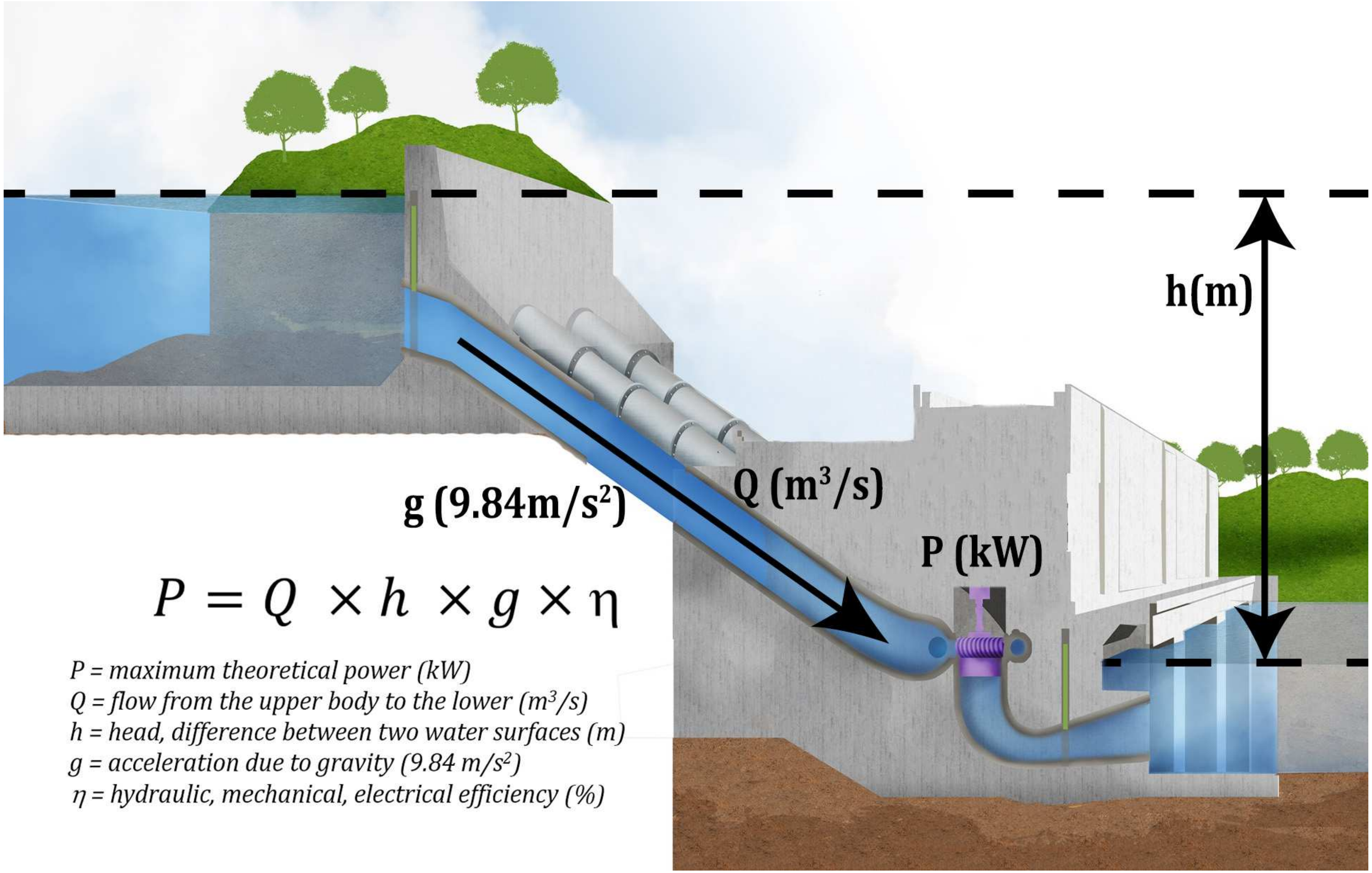
Key components of a hydropower station



1. Upper water body (reservoir / storage pond)
2. Intake structure
3. Penstock
4. Inlet valve / gate
5. Turbine
6. Generator
7. Tailrace (lower water body)
8. Lifting gantry
9. Control / automation
10. Transformer
11. Switchgear
12. Transmission line

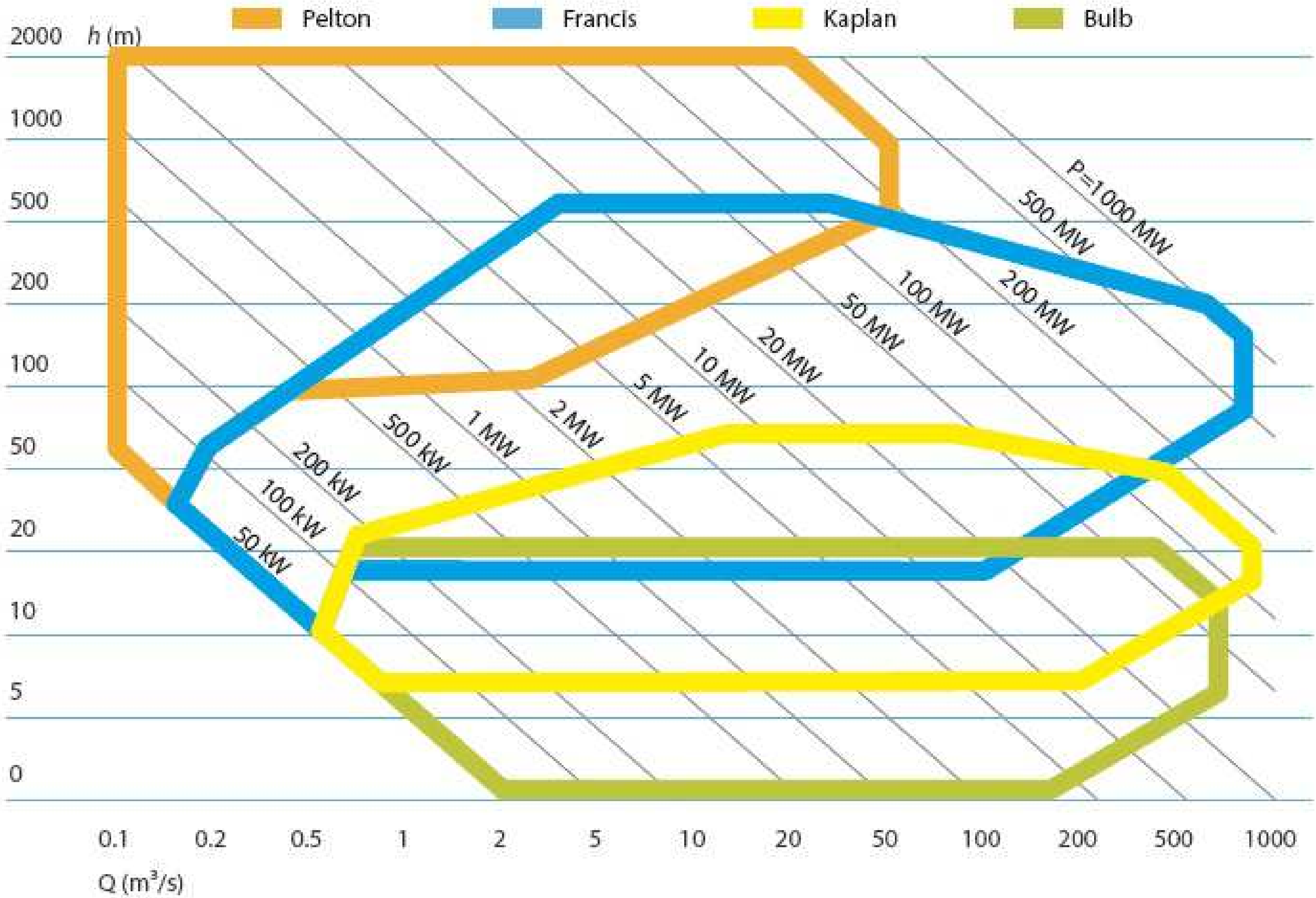
The hydropower equation



$$P = Q \times h \times g \times \eta$$

P = maximum theoretical power (kW)
Q = flow from the upper body to the lower (m^3/s)
h = head, difference between two water surfaces (m)
g = acceleration due to gravity (9.84 m/s^2)
η = hydraulic, mechanical, electrical efficiency (%)

Selection of turbine type



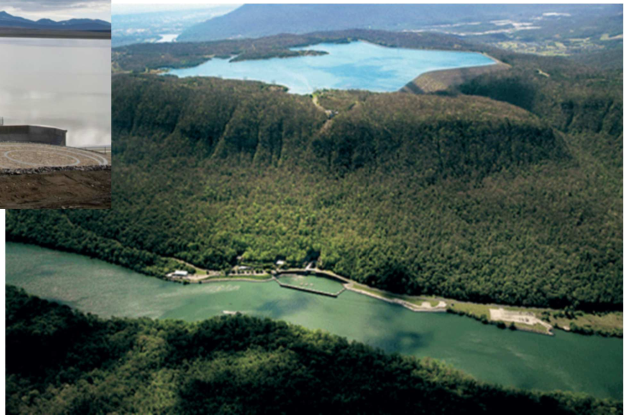
Types of hydropower

Run-of-river hydro

Hydropower typology,
covering all scales
of development

Storage hydro

Pump-storage hydro



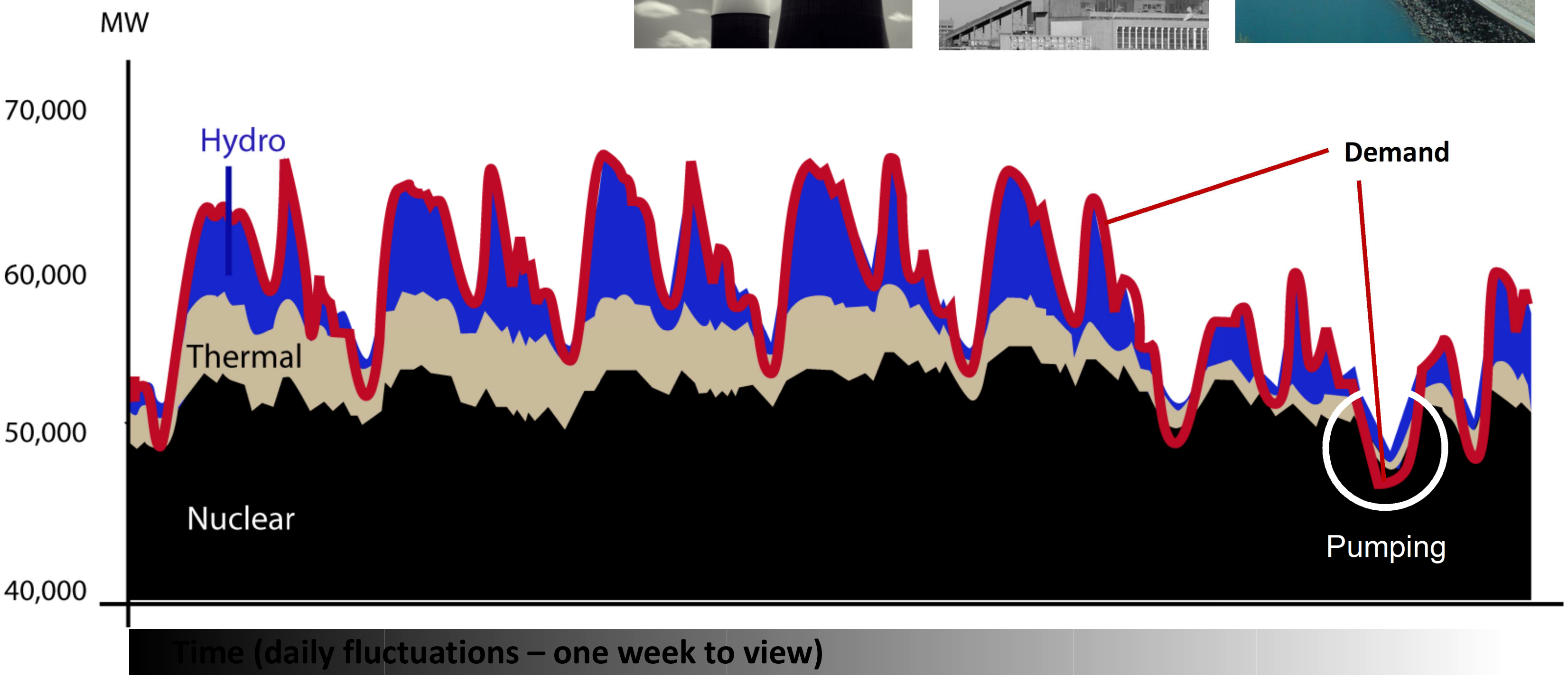
Base-load and flexible generation

Ex: France

Nuclear

Thermal

Hydropower



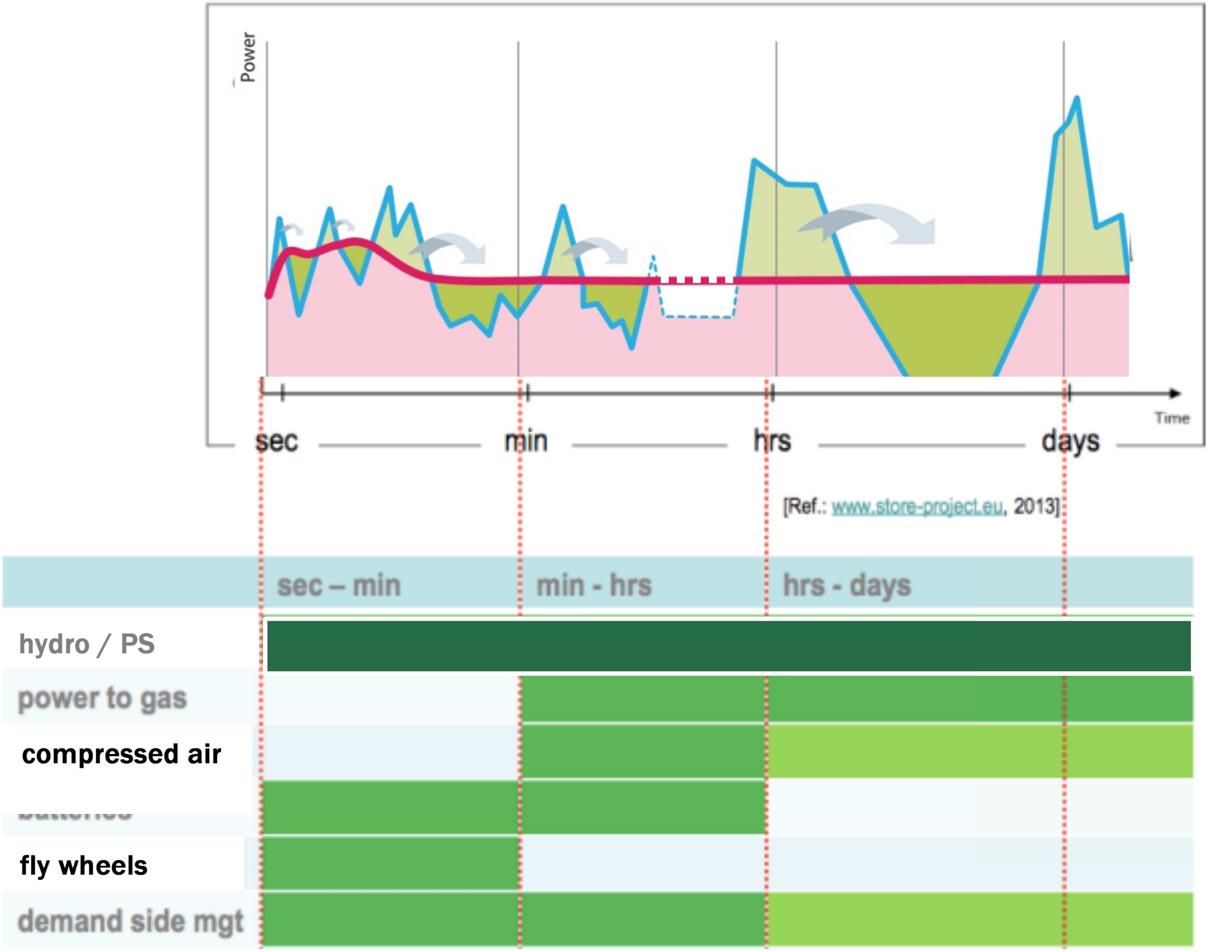
Schematic illustration

Hydropower's ancillary services

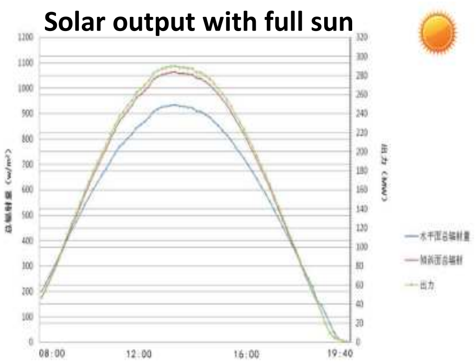
Ancillary markets

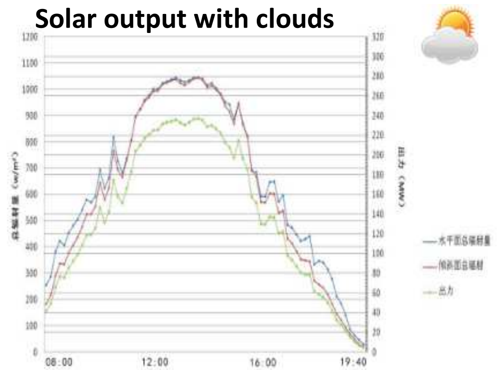
Hydropower's ancillary services:

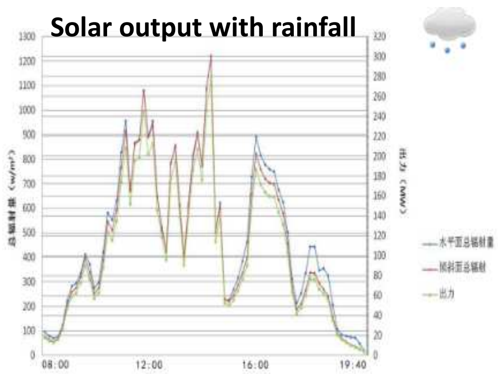
- Effective and efficient **storage of surplus** from RES and thermal
- **Fast power control** to meet load variations
- Guaranteed **power availability** for defined time frames



Synergy with other renewables



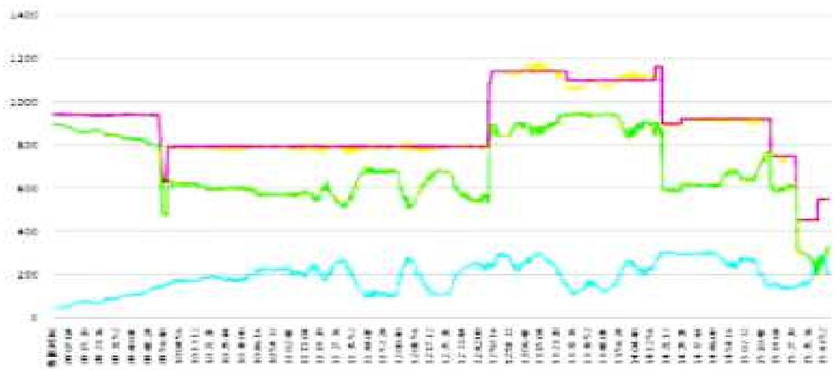




Demand for electricity

Counter-balanced hydro output

Variable solar output



Demand for electricity

Counter-balanced hydro output

Variable solar output

Multipurpose hydropower

Electricity generation and storage for:

- Power
- Heat
- Transport

Water storage for:

- Flood/drought protection
- Irrigation and aquaculture
- Water supply and Sanitation

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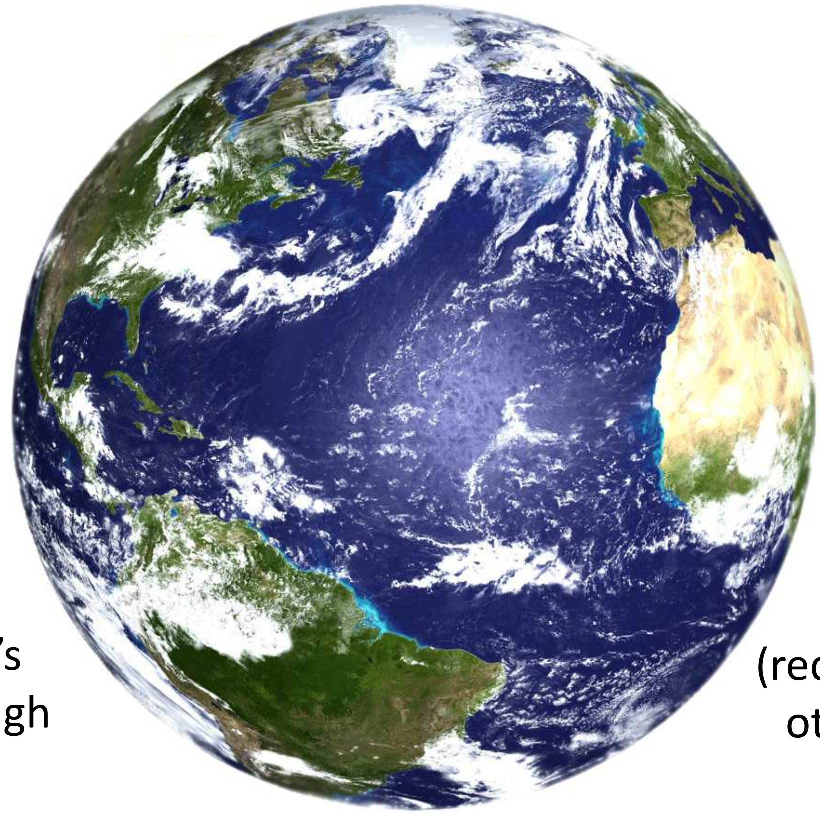
Hydropower and climate change

Hydropower and Climate Change

Climate resilience – adapting to change
(designing projects for increased hydrological variability including flood and drought mitigation capability)



GHG footprint
(evaluating hydro's own impact through construction and operation)

GHG offset
(reducing the pollution of other energy options by provision of more low-carbon electricity)

Hydropower and climate change

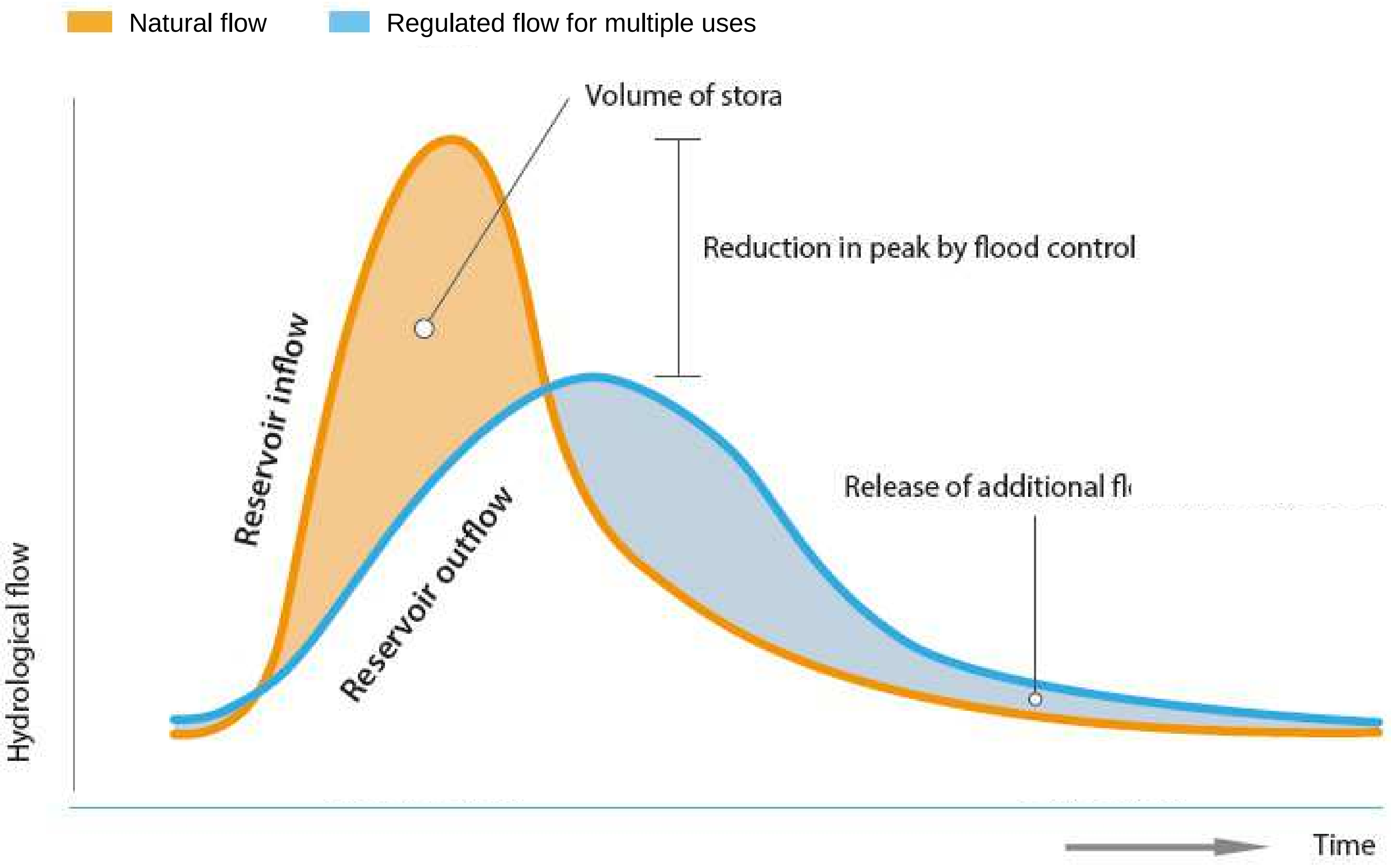
Hydropower and Climate Change

Climate resilience – adapting to change:

- **Intensive study of climate models and weather patterns (including precipitation type)**
- **Enhanced monitoring of hydrological characteristics**
- **Collaboration and knowledge-sharing between hydropower companies**
- **Scenario-driven safety assessment**
- **Scenario-driven business impact assessment**
- **Wider consideration of mitigation options (natural infrastructure, expanded interconnection, etc.**
- **Inclusion of climate change in future planning**
- **Building in contingency and flexibility in operations**
- **Assessing opportunities, as well as challenges**

Changing flow regime and changing value of water between users

Regional Hydropower (+Pumped Storage)

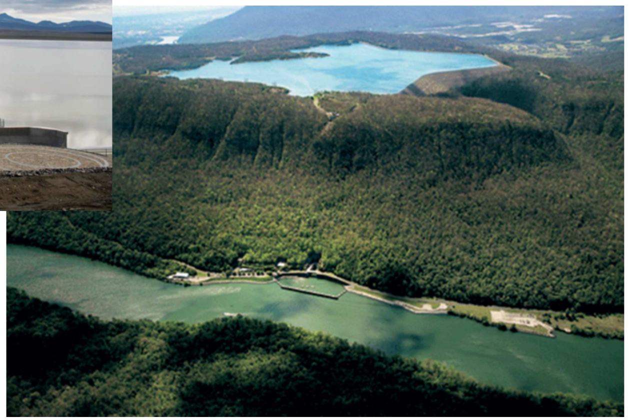


Capacity to adapt to climate change

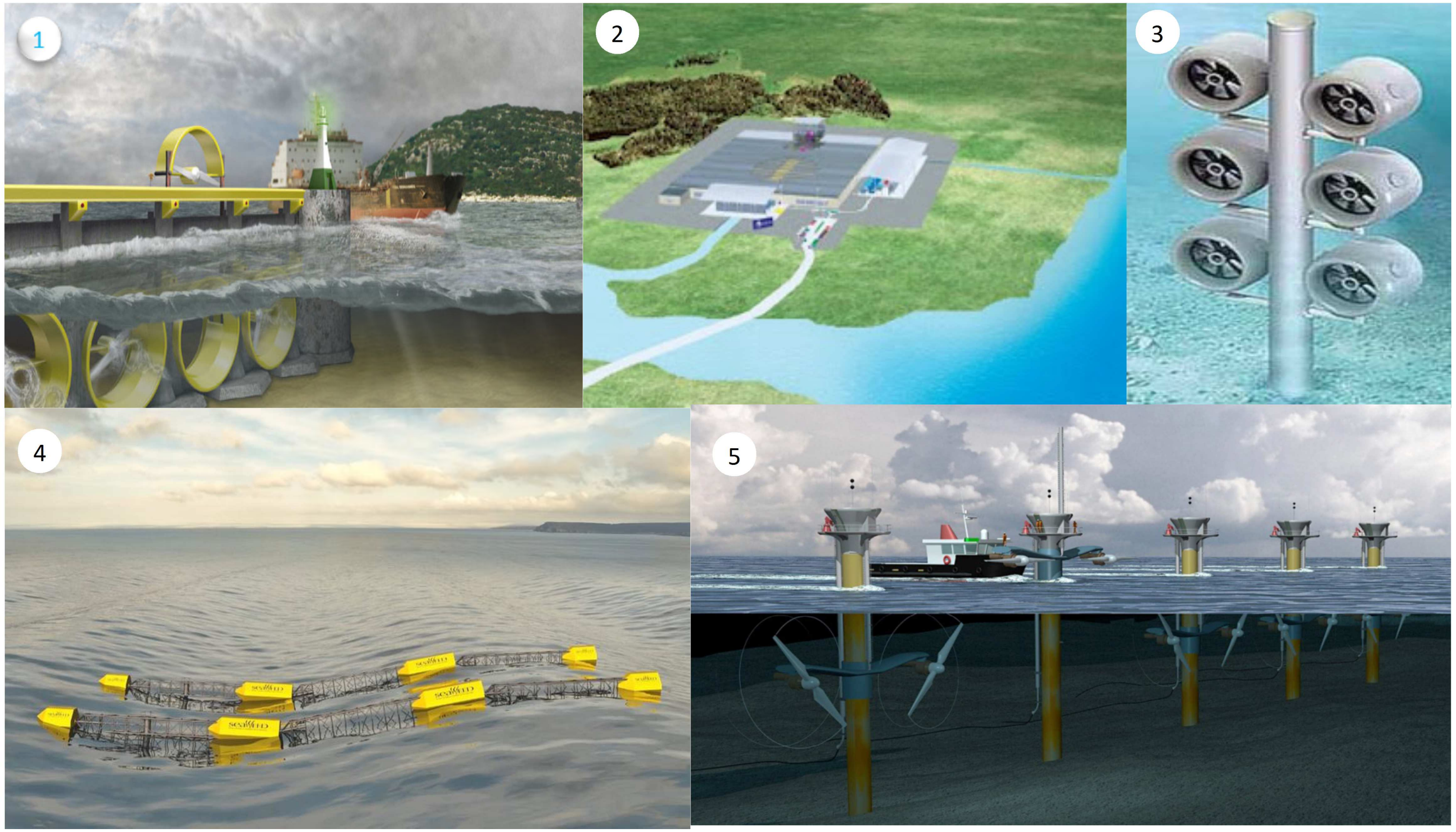
Run-of-river hydro

Storage hydro

Pump-storage hydro



Resilience to climate change / extreme events



Less established versions of hydropower:
1 = tidal barrage; 2 = osmotic; 3 = hydrokinetic;
4 = wave power; 5 = marine current

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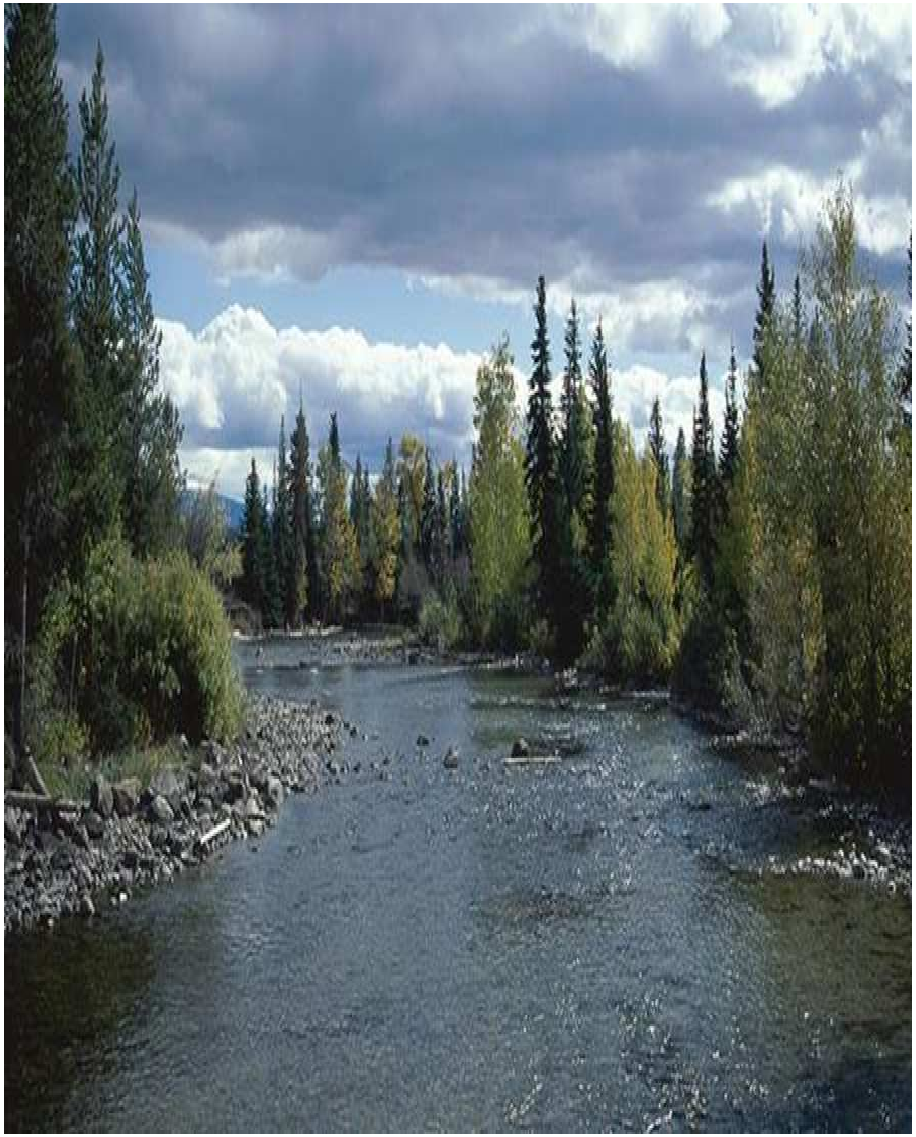
Flow regulation



Climate change will impact on river flows in terms of magnitude, duration, frequency, and seasonality

Hydro projects alter natural flow variation:

- Base load stations - consistent flow for long periods
- Peaking stations – rapid flow fluctuation over short periods

Typical management regimes:

- ✓ Guaranteed minimum flows,
- ✓ Caps on maximum flow releases,
- ✓ Constraints on draw-down or ramp-up rates,
- ✓ Provision of periodic flushing or flood flows

Current thinking moving from pure scientific approaches to interactive balancing of objectives:

- Ecological flow objectives - habitat availability for nominated species
- Social flow objectives - maintaining access to pumps
- Economic flow objectives - maximising electricity generation
- Different objectives may be in conflict with each other

Erosion and sedimentation

Climate change may impact on the hydraulic and sediment-transport characteristics of a river

- Reservoirs trap the natural sediment load in a river

- Downstream of power stations, reduced sediment loads may lead to erosion of the existing channel sediments

- Accumulation of sediment in a reservoir can significantly reduce the functional life span of a project

- Sediment accumulation can be managed:

  - ✓ through improved catchment management practices.
  - ✓ by-pass systems for floodwaters, gated structures for sediment flushing, sediment trapping and filtration systems, or direct dredging

- Erosion of reservoir bank can be caused by fluctuating reservoir level

- Shoreline erosion in reservoirs and downstream river systems can be reduced by changing project's operating

Water quality

Climate change may impact on water quality both in the reservoir and downstream

- Water quality issues can be caused by:
  - sediments and pollutants transported into the waterway from upstream sources
  - pollutants from operation of the infrastructure
  - changes to water flow and stratification of the reservoir
- Specific issues include reduced oxygenation, temperature, stratification, pollutant inflow, disease proliferation, nutrient capture, algal bloom and release of toxicants from inundated sediments.
- Catchment management and addressing upstream point sources of pollution can improve water quality entering the reservoir
- Management measures include:
  - ✓ Selective or multi-level offtakes in deep reservoirs
  - ✓ Stilling basins or spillways
  - ✓ Air injection facilities and aerating turbines
  - ✓ Baffles to direct circulation.
  - ✓ Planting of appropriately selected macrophytes

Biodiversity and invasive species

Climate change may affect biodiversity directly, indirectly and cumulatively

- Direct impacts:
    - Loss or changes to habitat due to inundation of land, land clearance and altered stream flows
    - Introduction of invasive species
    - Drowning during reservoir filling

- Indirect impacts:
    - Changes to riverine ecosystems in response to altered stream flow
    - Loss of a particular forest resource due to change in forest resource harvest

- Impacts may be acute, linked to the initial construction and commissioning of a project, or chronic, emerging over the operational life of the project

- Cumulative impacts occur where projects are developed in environments that are also affected by other activities

- Potential management measures:

    - ✓ Catchment protection, creation of reserves, and habitat conservation
    - ✓ Translocations or habitat rehabilitation
    - ✓ Offsets and compensation measures
    - ✓ Management of flow releases

Public health

Climate change may impact on public health issues

- Public health issues rely on good cooperation between the hydropower developers and the government health agencies.

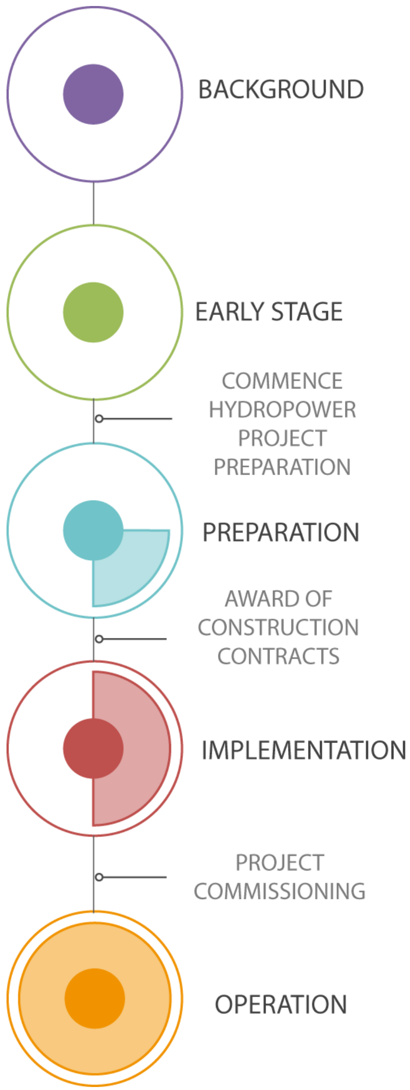
- Projects have the potential to provide improvements through through the provision of project benefits such as health facilities and health services that may not have previously existed.

- A public health plan would include the development of preventative measures such as disease prevention education and awareness campaigns, monitoring of vectors and disease outbreaks, and treatment of shallow reservoir areas.

Examples of public health issues include:

diseases introduced by construction workforce (e.g. HIV, Aids); vector borne diseases (e.g. malaria, schistosomiasis); communicable and non-communicable diseases, malnutrition, psychological disorders, social well-being; loss or contamination of traditional resources; mercury or heavy metal bio-accumulation.

The Hydropower Sustainability Assessment Protocol



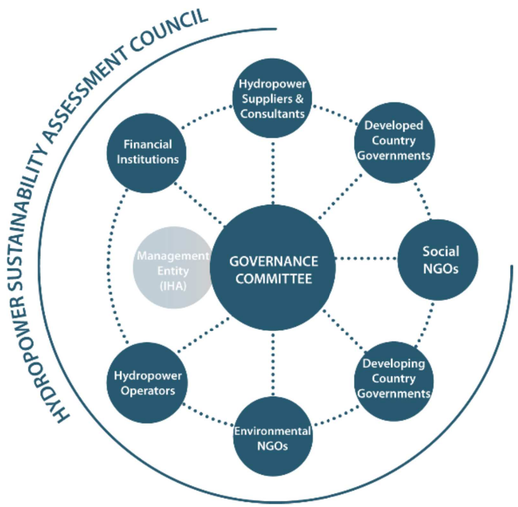
A **framework** to assess sustainability at all stages

A **consistent**, **globally-applicable** methodology, and a neutral **platform for dialogue**

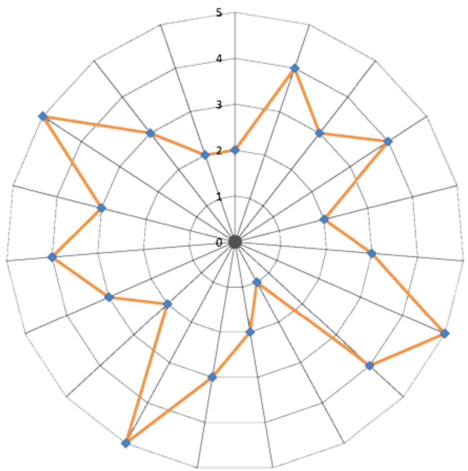
Over 20 clearly-defined sustainability **topics**

Governed by a multi-stakeholder Council and Terms and Conditions

4 project stages



Multi stakeholder governance



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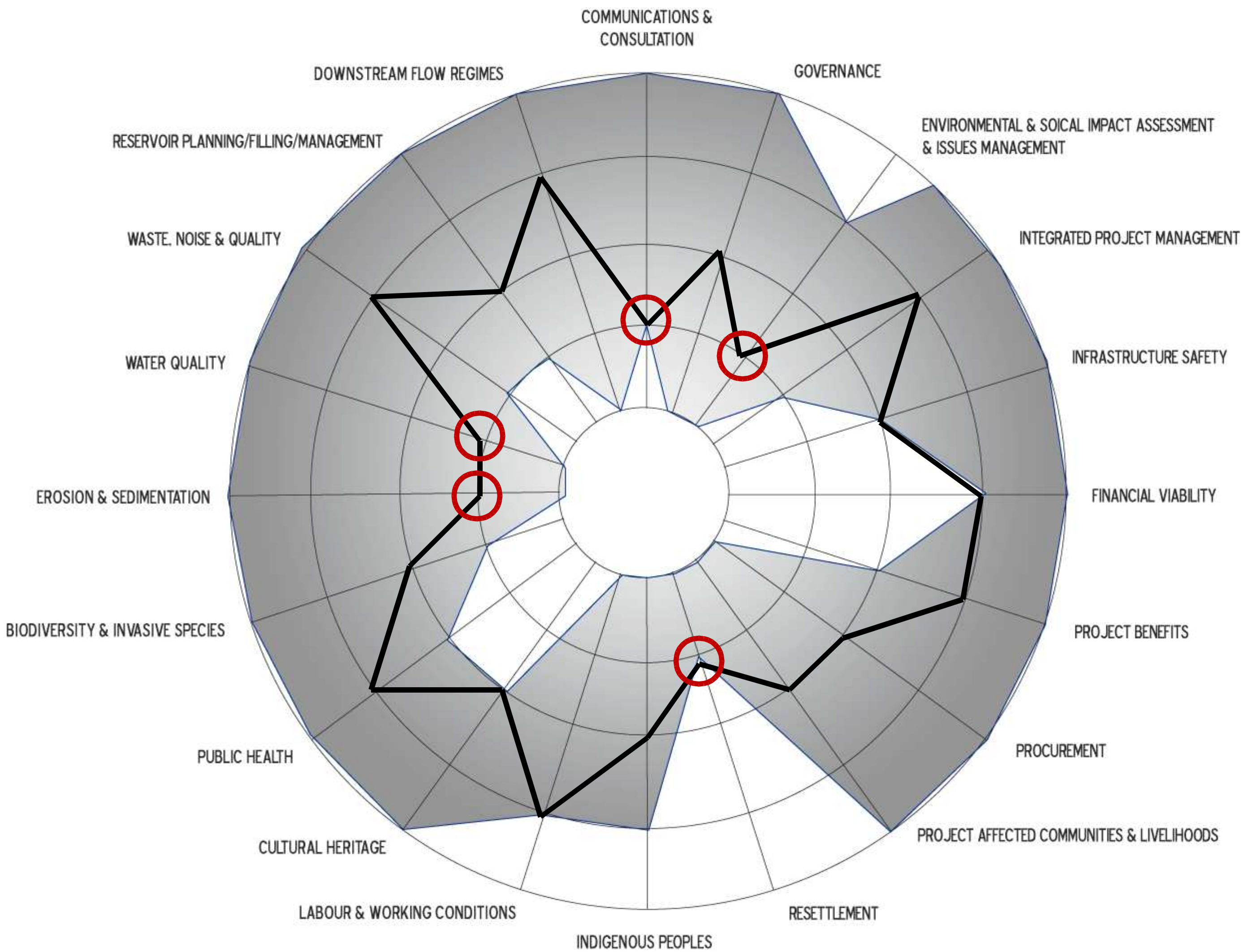
Clear results

Range of Protocol results observed to date



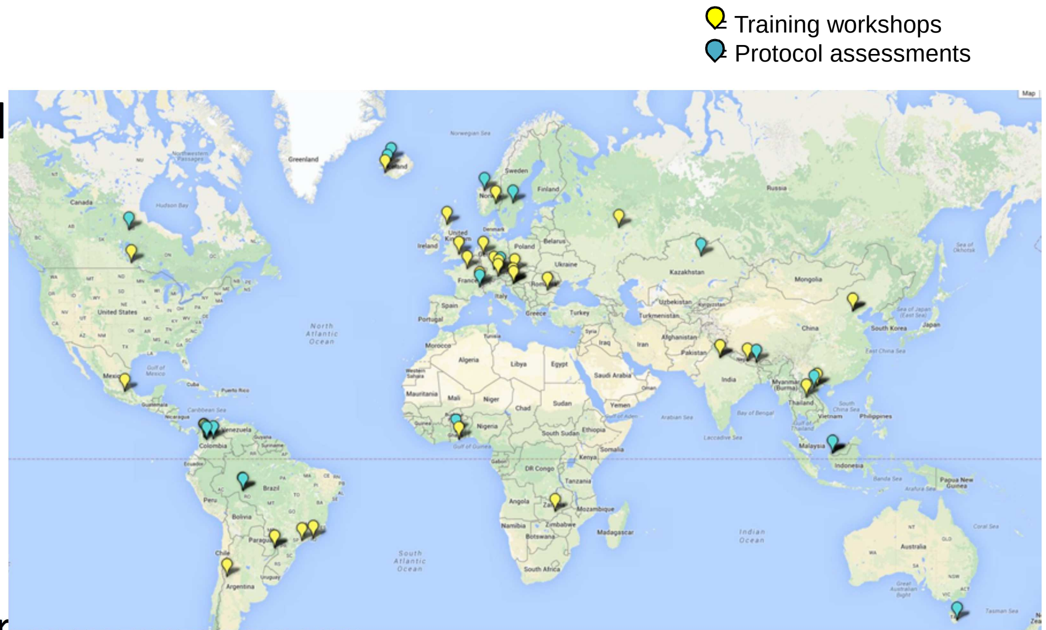
Criteria in every topic:

- Assessment
- Management
- Stakeholder Engagement
- Stakeholder Support
- Conformance / Compliance
- Outcomes

Added value to manage climate change

- **Management** of sustainability issues
- Independent **review** of sustainability issues
- **Comparison** with international good practice
- **Communication** with stakehold
- Facilitating access to **finance**

www.hydropowersustainability.org



www.hydrosustainability.org

Hydropower:

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